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## D2: DOSIMETRIC E-FIELD PROBE

**Calibration Laboratory of**  
**Schmid & Partner**  
**Engineering AG**  
**Zeughausstrasse 43, 8004 Zurich, Switzerland**



**S** Schweizerischer Kalibrierdienst  
**C** Service suisse d'étalonnage  
**S** Servizio svizzero di taratura  
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Accreditation No.: **SCS 108**

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Client

Expiry date: **ES3-3578\_May08**

## Calibration Certificate

Object

**EX3094 - SN3578**

Calibration procedure(s)

**EA4-CAL-07 v3, EA4-CAL-14 v3 and EA4-CAL-23 v3**  
**Calibration procedures for dielectric E-field probes**

Calibration date:

**May 20, 2008**

Condition of the calibrated item

**In operation**

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).  
 The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature  $(22 \pm 3)^\circ\text{C}$  and humidity  $< 70\%$ .

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter E4419B	GB41293874	1-Apr-08 (No. 217-00788)	Apr-09
Power sensor E4412A	MY41495277	1-Apr-08 (No. 217-00788)	Apr-09
Power sensor E4412A	MY41498087	1-Apr-08 (No. 217-00788)	Apr-09
Reference 3 dB Attenuator	SN: S5054 (3c)	8-Aug-07 (No. 217-00719)	Aug-08
Reference 20 dB Attenuator	SN: S5086 (20b)	31-Mar-08 (No. 217-00787)	Apr-09
Reference 30 dB Attenuator	SN: S5129 (30b)	8-Aug-07 (No. 217-00720)	Aug-08
Reference Probe ES3DV2	SN: 3013	2-Jan-08 (No. ES3-3013_Jan08)	Jan-09
DAE4	SN: 660	3-Sep-07 (No. DAE4-660_Sep07)	Sep-08

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
RF generator HP 8648C	US3642U01700	4-Aug-99 (in house check Oct-07)	In house check: Oct-09
Network Analyzer HP 8753E	US37390585	18-Oct-01 (in house check Oct-07)	In house check: Oct-08

Calibrated by:	Name	Function	Signature
	Klaus Peukert	Technical Manager	

Approved by:	Name	Function	Signature
	Emil Zehnholz	R&D Director	

Issued: May 21, 2008

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### **Glossary:**

TSL	tissue simulating liquid
NORM $x,y,z$	sensitivity in free space
ConvF	sensitivity in TSL / NORM $x,y,z$
DCP	diode compression point
Polarization $\phi$	$\phi$ rotation around probe axis
Polarization $\theta$	$\theta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\theta = 0$ is normal to probe axis

### **Calibration is Performed According to the Following Standards:**

- IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
- IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005

### **Methods Applied and Interpretation of Parameters:**

- NORM $x,y,z$ :** Assessed for E-field polarization  $\theta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). NORM $x,y,z$  are only intermediate values, i.e., the uncertainties of NORM $x,y,z$  does not effect the E<sup>2</sup>-field uncertainty inside TSL (see below ConvF).
- NORM(f) $x,y,z = NORMx,y,z * frequency\_response$**  (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCPx,y,z:** DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency nor media.
- ConvF and Boundary Effect Parameters:** Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM $x,y,z * ConvF$  whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from  $\pm 50$  MHz to  $\pm 100$  MHz.
- Spherical isotropy (3D deviation from isotropy):** in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset:** The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.

# Probe EX3DV4

## SN:3578

Manufactured:	November 4, 2005
Last calibrated:	April 24, 2007
Recalibrated:	May 20, 2008

Calibrated for DASY Systems

(Note: non-compatible with DASY2 system!)

**DASY - Parameters of Probe: EX3DV4 SN:3578**

Sensitivity in Free Space <sup>A</sup>			Diode Compression <sup>B</sup>		
NormX	<b>0.520</b> $\pm$ 10.1%	$\mu\text{V}/(\text{V}/\text{m})^2$	DCP X	98	mV
NormY	<b>0.500</b> $\pm$ 10.1%	$\mu\text{V}/(\text{V}/\text{m})^2$	DCP Y	90	mV
NormZ	<b>0.540</b> $\pm$ 10.1%	$\mu\text{V}/(\text{V}/\text{m})^2$	DCP Z	93	mV

### Sensitivity in Tissue Simulating Liquid (Conversion Factors)

**Please see Page 8.**

## Boundary Effect

**TSL**      **900 MHz**      **Typical SAR gradient: 5 % per mm**

Sensor Center to Phantom Surface Distance		2.0 mm	3.0 mm
SAR <sub>be</sub> [%]	Without Correction Algorithm	11.3	5.6
SAR <sub>be</sub> [%]	With Correction Algorithm	0.6	0.2

**TSL**      **1810 MHz**      **Typical SAR gradient: 10 % per mm**

Sensor Center to Phantom Surface Distance		2.0 mm	3.0 mm
SAR <sub>be</sub> [%]	Without Correction Algorithm	9.2	4.6
SAR <sub>be</sub> [%]	With Correction Algorithm	0.5	0.2

### Sensor Offset

Probe Tip to Sensor Center 1.0 mm

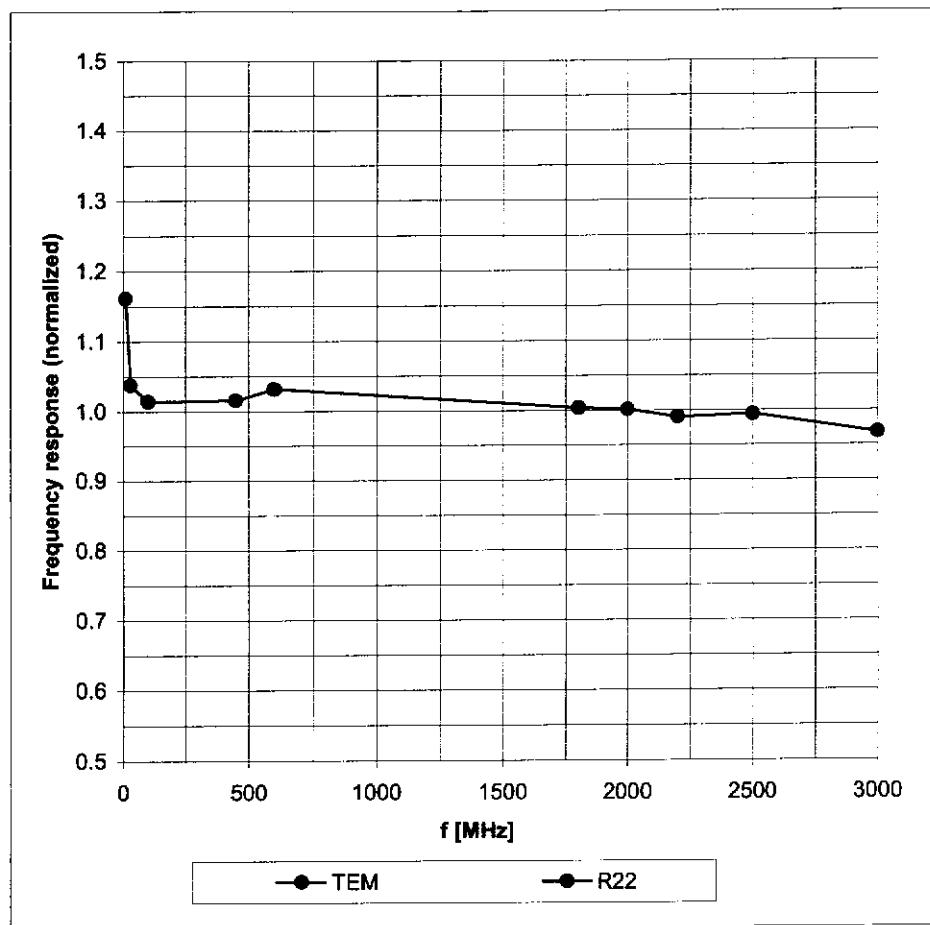
The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor  $k=2$ , which for a normal distribution corresponds to a coverage probability of approximately 95%.

<sup>a</sup> The uncertainties of NormX,Y,Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 8).

<sup>B</sup> Numerical linearization parameter: uncertainty not required.

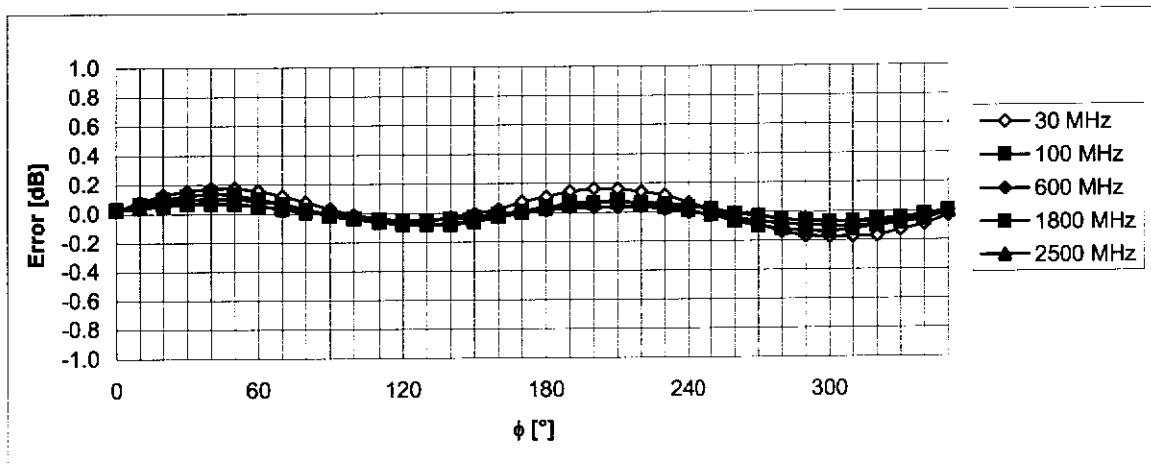
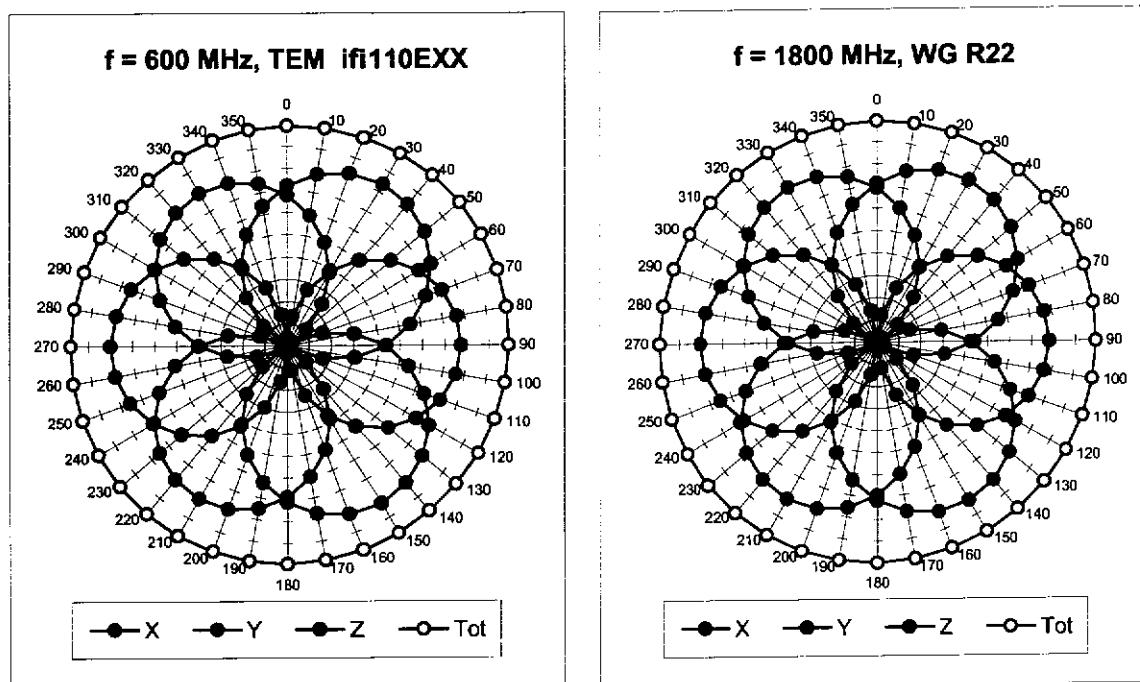
## Frequency Response of E-Field

(TEM-Cell:ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  (k=2)

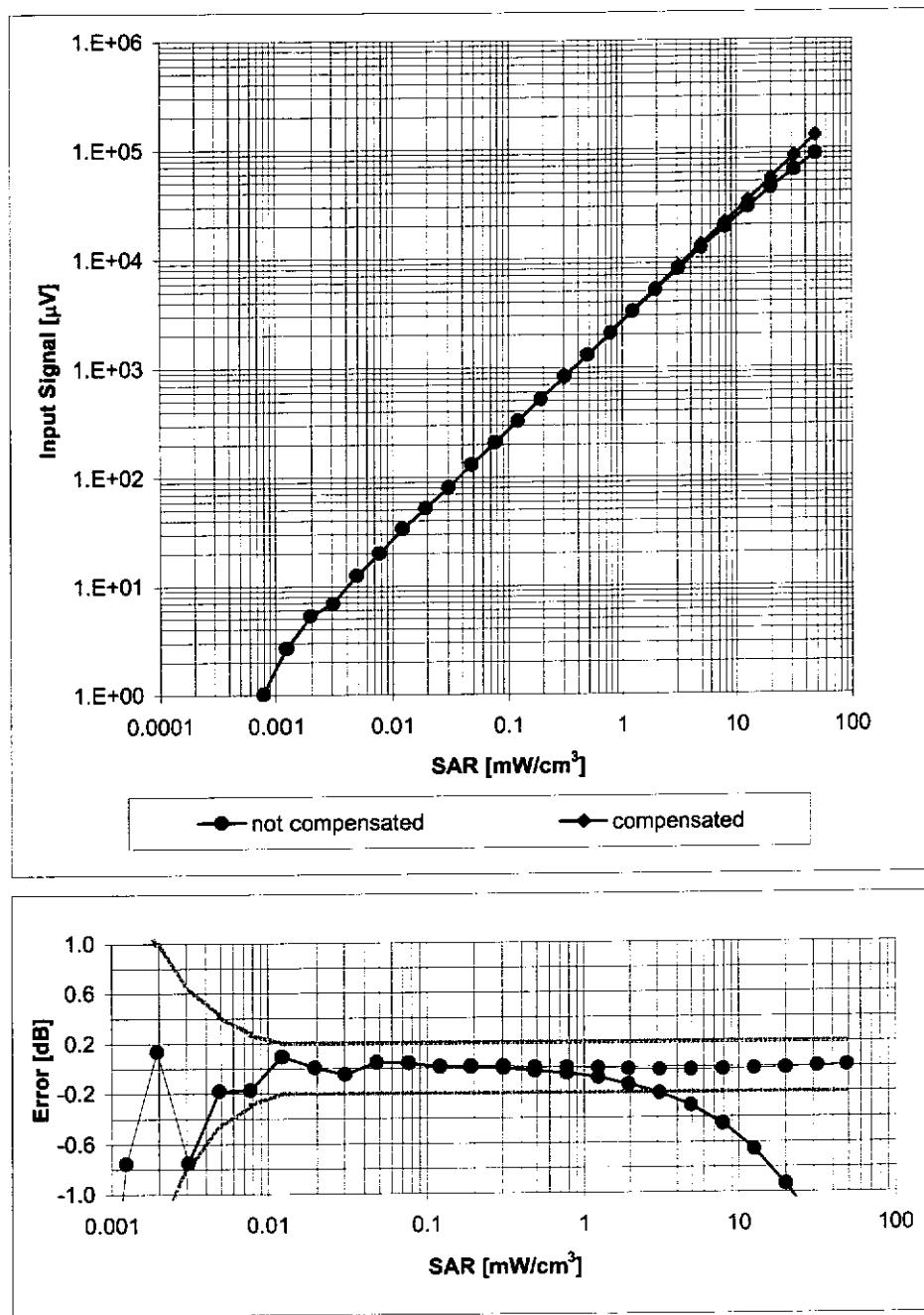
## Receiving Pattern ( $\phi$ ), $\theta = 0^\circ$



Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )

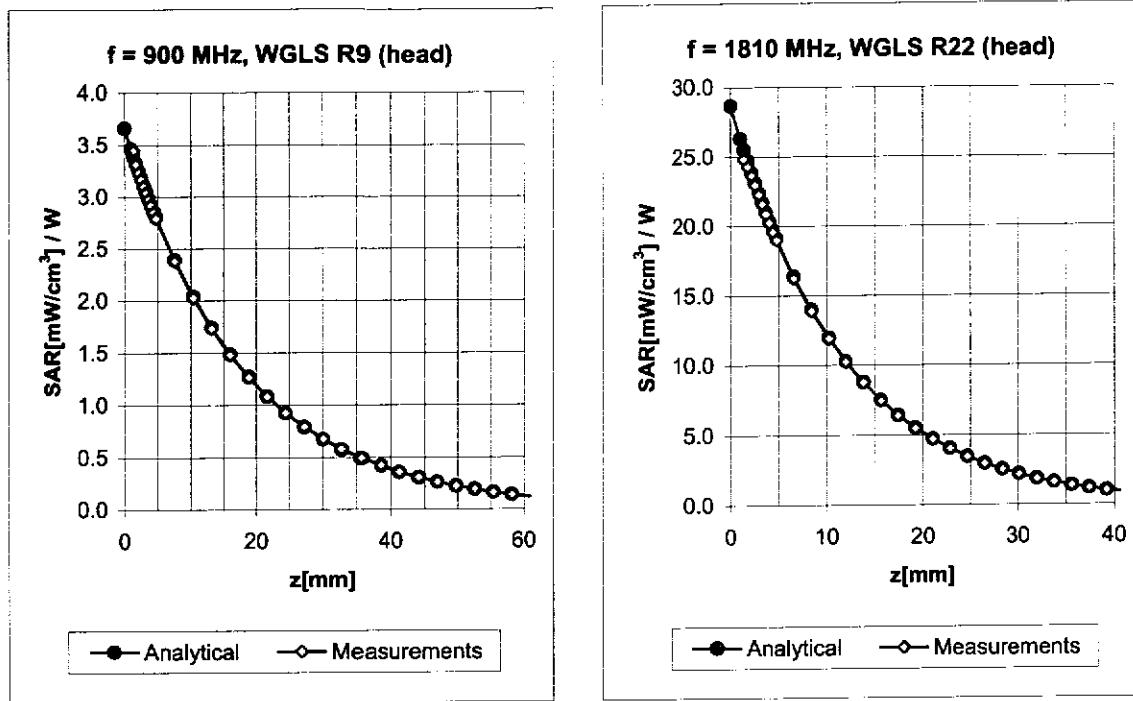
## Dynamic Range f(SAR<sub>head</sub>)

(Waveguide R22, f = 1800 MHz)



Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

## Conversion Factor Assessment

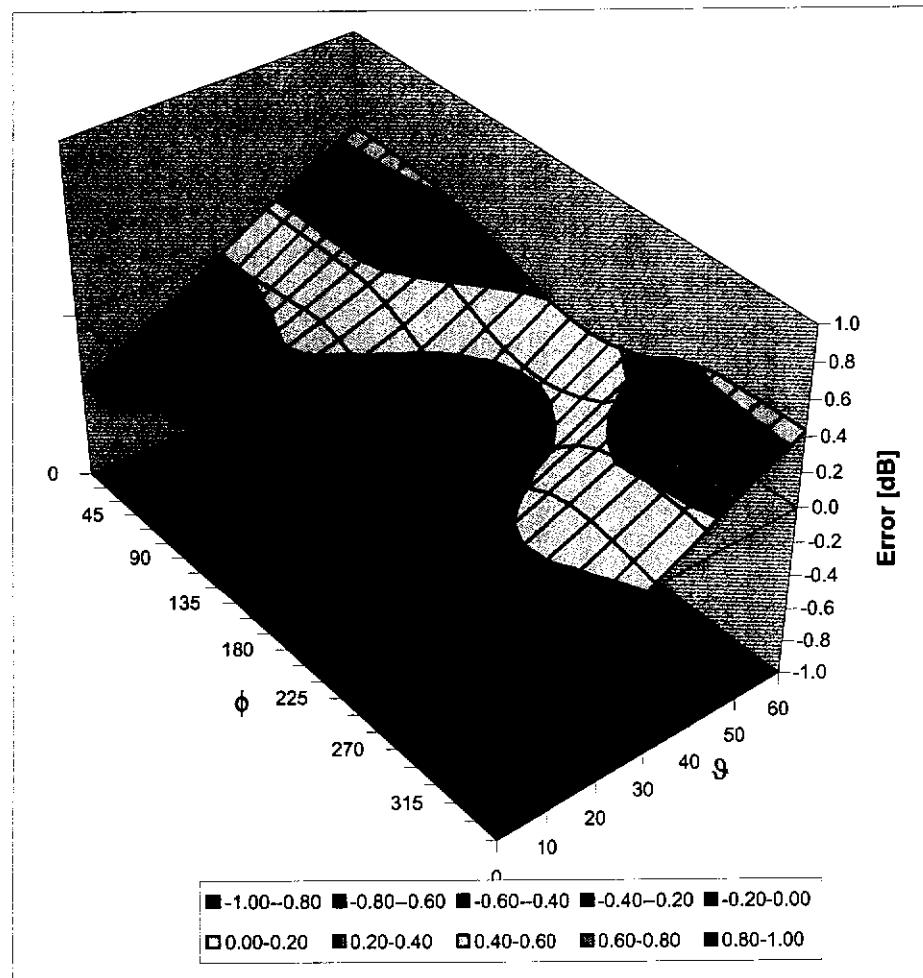


$f$ [MHz]	Validity [MHz] <sup>c</sup>	TSL	Permittivity	Conductivity	Alpha	Depth	ConvF	Uncertainty
900	$\pm 50 / \pm 100$	Head	$41.5 \pm 5\%$	$0.97 \pm 5\%$	0.48	0.80	8.55	$\pm 11.0\%$ (k=2)
1810	$\pm 50 / \pm 100$	Head	$40.0 \pm 5\%$	$1.40 \pm 5\%$	0.51	0.75	7.28	$\pm 11.0\%$ (k=2)
2000	$\pm 50 / \pm 100$	Head	$40.0 \pm 5\%$	$1.40 \pm 5\%$	0.48	0.77	7.10	$\pm 11.0\%$ (k=2)
2450	$\pm 50 / \pm 100$	Head	$39.2 \pm 5\%$	$1.80 \pm 5\%$	0.40	0.87	6.66	$\pm 11.0\%$ (k=2)
5200	$\pm 50 / \pm 100$	Head	$36.0 \pm 5\%$	$4.66 \pm 5\%$	0.43	1.70	4.65	$\pm 13.1\%$ (k=2)
5500	$\pm 50 / \pm 100$	Head	$35.6 \pm 5\%$	$4.96 \pm 5\%$	0.48	1.70	4.30	$\pm 13.1\%$ (k=2)
5800	$\pm 50 / \pm 100$	Head	$35.3 \pm 5\%$	$5.27 \pm 5\%$	0.50	1.70	4.22	$\pm 13.1\%$ (k=2)
900	$\pm 50 / \pm 100$	Body	$55.0 \pm 5\%$	$1.05 \pm 5\%$	0.45	0.80	8.42	$\pm 11.0\%$ (k=2)
1810	$\pm 50 / \pm 100$	Body	$53.3 \pm 5\%$	$1.52 \pm 5\%$	0.49	0.80	7.41	$\pm 11.0\%$ (k=2)
2000	$\pm 50 / \pm 100$	Body	$53.3 \pm 5\%$	$1.52 \pm 5\%$	0.43	0.87	7.08	$\pm 11.0\%$ (k=2)
2450	$\pm 50 / \pm 100$	Body	$52.7 \pm 5\%$	$1.95 \pm 5\%$	0.55	0.80	6.55	$\pm 11.0\%$ (k=2)
5200	$\pm 50 / \pm 100$	Body	$49.0 \pm 5\%$	$5.30 \pm 5\%$	0.47	1.75	3.84	$\pm 13.1\%$ (k=2)
5500	$\pm 50 / \pm 100$	Body	$48.6 \pm 5\%$	$5.65 \pm 5\%$	0.35	1.75	4.12	$\pm 13.1\%$ (k=2)
5800	$\pm 50 / \pm 100$	Body	$48.2 \pm 5\%$	$6.00 \pm 5\%$	0.46	1.75	3.92	$\pm 13.1\%$ (k=2)

<sup>c</sup> The validity of  $\pm 100$  MHz only applies for DASY v4.4 and higher (see Page 2). The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

## Deviation from Isotropy in HSL

Error ( $\phi, \theta$ ),  $f = 900$  MHz



Uncertainty of Spherical Isotropy Assessment:  $\pm 2.6\%$  ( $k=2$ )



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### D3: DAE

## **IMPORTANT NOTICE**

### **USAGE OF THE DAE 4**

The DAE unit is a delicate, high precision instrument and requires careful treatment by the user. There are no serviceable parts inside the DAE. Special attention shall be given to the following points:

**Battery Exchange:** The battery cover of the DAE4 unit closed using a screw, over tightening the screw may cause the threads inside the DAE to wear out .

**Shipping of the DAE:** Before shipping the DAE to SPEAG for calibration Customer shall remove the batteries and pack the DAE in an antistatic bag. The packaging shall protect the DAE from impacts during transportation. The package shall be marked to indicate that a fragile instrument is inside.

**E-Stop Failures:** Touch detection may be malfunctioning due to broken magnets in the E-stop. Rough handling of the E-stop may lead to damage of these magnets. Touch and collision errors are often caused by dust and dirt accumulated in the E-stop. To prevent E-stop failure, Customer shall always mount the probe to the DAE carefully and keep the DAE unit in a non-dusty environment if not used for measurements.

**Repair:** Minor repairs are performed at no extra cost during the annual calibration. However, SPEAG reserves the right to charge for any repair especially if rough unprofessional handling caused the defect.

**Important Note:**

**Warranty and calibration is void if the DAE unit is disassembled partly or fully by the Customer.**

**Important Note:**

**Never attempt to grease or oil the E-stop assembly. Cleaning and readjusting of the E-stop assembly is allowed by certified SPEAG personnel only and is part of the annual calibration procedure.**



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Accreditation No.: **SCS 108**

Client **Jabil Circuits (Auden)**

Certificate No: **DAE4-861\_Sep08**

## CALIBRATION CERTIFICATE

Object	DAE4 - SD 000 D04 BG - SN: 861		
Calibration procedure(s)	QA CAL-06.v12 Calibration procedure for the data acquisition electronics (DAE)		
Calibration date:	September 22, 2008		
Condition of the calibrated item	In Tolerance		
<p>This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.</p> <p>All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity &lt; 70%.</p> <p>Calibration Equipment used (M&amp;TE critical for calibration)</p>			
Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Fluke Process Calibrator Type 702	SN: 6295803	04-Oct-07 (No: 6467)	Oct-08
Keithley Multimeter Type 2001	SN: 0810278	03-Oct-07 (No: 6465)	Oct-08
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Calibrator Box V1.1	SE UMS 006 AB 1004	06-Jun-08 (in house check)	In house check: Jun-09

Calibrated by:	Name Andrea Guntli	Function Technician	Signature 
Approved by:	Fin Bomholt	R&D Director	

Issued: September 25, 2008

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## Glossary

DAE	data acquisition electronics
Connector angle	information used in DASY system to align probe sensor X to the robot coordinate system.

## Methods Applied and Interpretation of Parameters

- *DC Voltage Measurement*: Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity*: Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity*: Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation*: Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted*: Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement*: Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current*: Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance*: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage*: Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption*: Typical value for information. Supply currents in various operating modes.

## DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB =  $6.1\mu\text{V}$ , full range =  $-100...+300\text{ mV}$

Low Range: 1LSB =  $61\text{nV}$ , full range =  $-1.....+3\text{mV}$

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	$404.365 \pm 0.1\% \text{ (k=2)}$	$404.742 \pm 0.1\% \text{ (k=2)}$	$405.670 \pm 0.1\% \text{ (k=2)}$
Low Range	$4.02029 \pm 0.7\% \text{ (k=2)}$	$3.98762 \pm 0.7\% \text{ (k=2)}$	$4.01204 \pm 0.7\% \text{ (k=2)}$

## Connector Angle

Connector Angle to be used in DASY system	$124^\circ \pm 1^\circ$
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## Appendix

### 1. DC Voltage Linearity

High Range		Input (µV)	Reading (µV)	Error (%)
Channel X	+ Input	200000	199999.9	0.00
Channel X	+ Input	20000	20002.71	0.01
Channel X	- Input	20000	-20003.54	0.02
Channel Y	+ Input	200000	200000.3	0.00
Channel Y	+ Input	20000	19999.17	0.00
Channel Y	- Input	20000	-20003.37	0.02
Channel Z	+ Input	200000	199999.8	0.00
Channel Z	+ Input	20000	20000.36	0.00
Channel Z	- Input	20000	-20005.96	0.03

Low Range		Input (µV)	Reading (µV)	Error (%)
Channel X	+ Input	2000	2000	0.00
Channel X	+ Input	200	199.92	-0.04
Channel X	- Input	200	-200.25	0.13
Channel Y	+ Input	2000	1999.9	0.00
Channel Y	+ Input	200	199.32	-0.34
Channel Y	- Input	200	-200.67	0.33
Channel Z	+ Input	2000	2000	0.00
Channel Z	+ Input	200	199.65	-0.18
Channel Z	- Input	200	-201.81	0.91

### 2. Common mode sensitivity

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Common mode Input Voltage (mV)	High Range Average Reading (µV)	Low Range Average Reading (µV)
Channel X	200	5.10	4.08
	-200	-4.32	-4.27
Channel Y	200	1.83	1.39
	-200	-2.21	-3.06
Channel Z	200	-10.14	-10.20
	-200	8.87	7.81

### 3. Channel separation

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	Input Voltage (mV)	Channel X (µV)	Channel Y (µV)	Channel Z (µV)
Channel X	200	-	3.33	0.83
Channel Y	200	0.10	-	4.12
Channel Z	200	-0.22	0.96	-

#### 4. AD-Converter Values with inputs shorted

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

	High Range (LSB)	Low Range (LSB)
Channel X	15980	15973
Channel Y	16090	15869
Channel Z	16031	16364

#### 5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Input  $10M\Omega$

	Average ( $\mu$ V)	min. Offset ( $\mu$ V)	max. Offset ( $\mu$ V)	Std. Deviation ( $\mu$ V)
Channel X	-0.05	-2.16	1.46	0.57
Channel Y	-0.73	-2.87	1.71	0.55
Channel Z	-1.37	-4.32	0.61	0.75

#### 6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

#### 7. Input Resistance

	Zeroing (M $\Omega$ )	Measuring (M $\Omega$ )
Channel X	0.1999	197.8
Channel Y	0.2000	200.0
Channel Z	0.1999	198.0

#### 8. Low Battery Alarm Voltage (verified during pre test)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

#### 9. Power Consumption (verified during pre test)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.0	+6	+14
Supply (- Vcc)	-0.01	-8	-9